

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method of producing an elemental material or an alloy thereof from a halide of the elemental material or halide mixtures comprising introducing the vapor halide of an elemental material or halide mixtures thereof into a liquid phase of a reducing metal of an alkali metal or alkaline earth metal or mixtures thereof present in excess of the amount needed to reduce the halide vapor to the elemental material or alloy resulting in an exothermic reaction between the vapor halide and the liquid reducing metal producing particulate elemental material or alloy thereof and the halide salt of the reducing metal and sufficient heat to vaporize substantially all the excess reducing metal, and separating the vapor of the reducing metal from the particulate elemental material or alloy thereof.
2. The method of claim 1, wherein the elemental material or alloy is one or more of Ti, Al, Sb, Be, B, Ga, Mo, Nb, Ta, V, Zr, U, Re, Si, Os, Ir and mixtures thereof.
3. The method of claim 2, wherein the reducing metal is an alkali metal.
4. The method of claim 3, wherein the reducing metal is Na.
5. The method of claim 3, wherein the liquid phase is Na present in excess of the stoichiometric amount required for the reduction of the halide of the elemental material or mixtures in the range of from about 25% to 125% by weight.
6. The method of claim 3, wherein the liquid phase is Na present in excess of the stoichiometric amount required for the reduction of the halide of the elemental material or mixtures in the range of from about 25% to about 85% by weight.
7. The method of claim 3, wherein the halide is a chloride and the liquid phase is Na present in excess of the stoichiometric amount required for the reduction of the chloride of the elemental material or mixtures in the range of from about 25% to 125% by weight.
8. The method of claim 7, wherein the elemental material is titanium and the Na is present in excess of the stoichiometric amount required for the reduction of the chloride of the elemental material or mixtures in the range of from about 25% to about 85% by weight.

9. The method of claim 7, wherein the elemental material or an alloy thereof includes titanium and the Na is flowing.

10. The method of claim 2, wherein the reducing metal is an alkaline earth metal.

11. The method of claim 10, wherein the reducing metal is Mg.

12. The method of claim 10, wherein the halide is a chloride and the liquid phase is Mg present in excess of the stoichiometric amount required for the reduction of the halide of the elemental material or mixtures in the range of from about 5% to 150% by weight.

13. The method of claim 10, wherein the liquid phase is Mg present in excess of the stoichiometric amount required for the reduction of the halide of the elemental material or mixtures in the range of from about 5% to about 75% by weight.

14. The method of claim 12, wherein the elemental material or alloy thereof includes titanium and the Mg is flowing.

15. The method of claim 2, wherein the alloy is substantially Ti and Al and V and is formed by introducing the chlorides thereof as vapor into a liquid phase of a reducing metal.

16. The method of claim 2, wherein the reducing metal vapor is separated from the particulate reaction products with an inert sweep gas.

17. The method of claim 16, wherein the reducing metal is Na, the inert sweep gas is Ar and the alloy is Ti - 6% by weight Al- 4% by weight V.

18. The method of claim 16, wherein the reducing metal is Mg, the inert sweep gas is Ar and the alloy is Ti-6% by weight Al - 4% by weight V.

19. The method of claim 1, wherein the temperature of the particulate elemental material or alloy thereof is maintained at or below the boiling point of the halide salt of the alkali metal or alkaline earth metal.

20. The method of claim 16, wherein the inert sweep gas flows countercurrently to the particulate reaction products.

21. The method of claim 16, wherein the inert sweep gas flows co-currently with the particulate reaction products; and filtering the particulate reaction

products from the sweep gas and the reducing metal vapor.

22. The method of claim 1, wherein the reducing metal vapor is separated from the particulate reaction products by condensing the vapor at a location remote from the reaction products.

23. The method of claim 1, wherein the particulate reaction products are cooled before separation of the halide salt from elemental material or alloy thereof.

24. The method of claim 1, wherein the particulate elemental material or alloy thereof is cooled below the sintering temperature before the particulate material or alloy thereof agglomerates.

25. The method of claim 1, wherein formation of the particulate elemental material or alloy thereof is at atmospheric pressure and the separation of the reducing metal vapor is at or below atmospheric pressure.

26. The method of claim 1, wherein the temperature of the particulate reaction products does not exceed the boiling point of the halide salt produced.

27. The method of claim 26, wherein the temperature of the particulate reaction products is maintained at or above the boiling point of the reducing metal until the reducing metal vapor is entirely separated from the particulate reaction products.

28. A method of producing Ti or a Ti alloy comprising introducing a Ti chloride vapor or a mixture of Ti chloride and other chloride vapors into a liquid continuum of a reducing metal of an alkali metal or alkaline earth metal or mixtures thereof initiating an exothermic reaction to form particulate Ti or Ti alloy and a chloride salt of the reducing metal, the reducing metal being present in excess of the stoichiometric amount required to react with the Ti chloride or mixture of Ti chloride and other chloride vapor, the exothermic reaction producing heat sufficient to vaporize substantially all the excess reducing metal, and separating the reducing metal vapor from the particulate Ti or Ti alloy and the chloride salt of the reducing metal.

29. The method of claim 28, wherein the formation of particulate Ti or alloy thereof and separation of reducing metal vapor is at substantially atmospheric pressure.

30. The method of claim 28, wherein the formation of particulate Ti or alloy thereof is at substantially atmospheric pressure and the separation of the reducing metal is in part at less than atmospheric pressure.

31. The method of claim 28, wherein the reducing metal is Na and the temperature of the particulate Ti or Ti alloy is maintained at or below the boiling point of NaCl.

32. The method of claim 28, wherein the reducing metal is Mg and the temperature of the particulate Ti or Ti alloy is maintained at or below the boiling point of MgCl_2 .

33. The method of claim 28, wherein reducing metal vapor is separated from the particulate reaction products with an inert sweep gas.

34. The method of claim 28, wherein the particulate reaction products are cooled with an inert sweep gas.

35. The method of claim 28, wherein the chloride vapor is introduced into a flowing stream of reducing metal.

36. The method of claim 35, wherein the particulate Ti or Ti alloy is cooled below the sintering temperature thereof before the particulate Ti or Ti alloy agglomerates.

37. The method of claim 28, wherein the reducing metal vaporized during the formation of the reaction products is maintained in the vapor phase and is separated from the reaction products by condensing the reducing metal thereby creating an area of reduced pressure into which a reducing metal vapor is drawn.

38. A method of producing Ti or a Ti alloy, comprising producing Ti or Ti alloy particulates in an exothermic reaction by introducing Ti chloride vapor or a mixture of Ti chloride and other chloride vapor into a flowing stream of liquid reducing metal of an alkali metal or an alkali earth metal or mixtures thereof, the reducing metal being present in an amount in excess of the stoichiometric amount required to react all of the Ti chloride or mixtures of Ti chloride and other chloride vapor, the heat of reaction vaporizing the excess liquid reducing metal such that substantially no reducing metal is present as a liquid after the reaction, the Ti or Ti alloy particulates moving in a first direction through a vessel, establishing a flow of inert gas to contact the Ti or Ti alloy particulates to separate the substantially all

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the excess reducing metal vapor from the Ti or Ti alloy particulates, and removing the Ti or Ti alloy particulates from the vessel.

39. The method of claim 38, wherein first direction is generally downwardly and the inert gas flows generally upwardly.

40. The method of claim 38, wherein a Ti alloy is produced by mixing TiCl_4 and AlCl_3 .

41. The method of claim 38, wherein a Ti alloy is produced by mixing TiCl_4 and a V chloride.

42. The method of claim 38, wherein a Ti alloy is produced by mixing chlorides of Ti and Al and V in a predetermined weight ratio and thereafter reducing the mixture to an alloy of Ti and Al and V.

43. The method of claim 43, wherein the Ti and Al and V alloy includes about 6% by weight Al and about 4% by weight V, the balance being substantially Ti.

44. The method of claim 43, wherein the reducing metal is Na and the inert gas is Ar.

45. The method of claim 38, wherein the inert gas cools the Ti or Ti alloy particulates.

46. A method of producing Ti or a Ti alloy, comprising producing Ti or Ti alloy particulates from an exothermic reaction by introducing Ti chloride vapor or a mixture of Ti chloride and other chloride vapor into a flowing stream of liquid reducing metal of Na or Mg, the reducing metal being present in an amount in excess of the stoichiometric amount required to react all of the Ti chloride or mixtures of Ti chloride and other chloride vapor, the heat of reaction vaporizing substantially all the excess Na or Mg such that substantially no Na or Mg is present as a liquid after the reaction, the Ti or Ti alloy particulates moving downwardly through a vessel, establishing a flow of inert gas upwardly through the vessel for cooling the particulates and separating the excess Na or Mg vapor from the particulates, and removing the Ti or Ti alloy particulates from the vessel.

47. The method of claim 46, wherein the reducing metal is Na.

48. The method of claim 47, wherein the liquid Na is present in an amount of about 25% to 85% by weight in excess of the stoichiometric amount required for the reduction of the Ti chloride or mixtures of Ti chloride and other chloride vapor.

49. The method of claim 46, wherein the reducing metal is Mg.

50. The method of claim 49, wherein the Mg is present in an amount of about 5% to about 75% by weight in excess of the stoichiometric amount required for the reduction of the Ti chloride or mixture of Ti chloride and other chloride vapor.

51. A method of producing Ti particles substantially free of Na, comprising introducing TiCl_4 vapor into a liquid continuum of Na to produce Ti particles and NaCl and heat in an exothermic reaction, the Na being present in an amount in the range of about 25% to 125% by weight in excess of the stoichiometric amount of Na needed to reduce all the TiCl_4 to Ti, the temperature of the reaction products of Ti and NaCl particles being maintained at less than about the boiling point of NaCl and greater than the boiling point of Na after the chemical reaction of TiCl_4 and Na such that substantially all excess Na is in the vapor phase, the Na vapor being separated from the reaction products of NaCl and Ti with a moving gas, and thereafter separating the Ti from the NaCl.

52. The method of claim 51, wherein one or more other chlorides are mixed with the TiCl_4 prior to contact with the reducing metal to produce particles of Ti alloy.

53. The method of claim 52, wherein the chlorides mixed with TiCl_4 are Al chloride and V chloride.

54. The method of claim 53, wherein the alloy is about 6% by weight Al and about 4% by weight V and the balance substantially all Ti.

55. The method of claim 51, wherein the process is conducted at atmospheric pressure.

56. The method of claim 51, wherein the moving gas is inert with respect to Na and Ti and NaCl.

57. The method of claim 56, wherein the inert gas is Argon.

58. The method of claim 57, wherein the Ti is separated from the NaCl by dissolving the NaCl in water.

59. The method of claim 58, wherein the Na is present in the range of from about 25% by weight to about 85% by weight in excess of the stoichiometric amount needed to reduce the TiCl_4 to Ti.

60. A system for the production of Ti or a Ti alloy, comprising a reactor for introducing a Ti halide vapor or a mixture of Ti halide and other metal halide vapor into a continuous phase of a liquid reducing metal to initiate an exothermic reaction reducing the halide vapor to produce reaction products of Ti or Ti alloy particulates and the halide of the reducing metal, the reducing metal being present in an amount greater than the stoichiometric amount needed to reduce the halide or halides but only in the amount which will substantially vaporize during the reaction, such that substantially no liquid reducing metal is present in the reaction products, a chamber wherein the reaction products are separated from the reducing metal vapor and the reaction products are cooled, and a separator in which the halides of the reducing metal are separated from the Ti or Ti alloy particulates by washing with water.

61. The system of claim 60, wherein said reactor is positioned in said chamber and further including a condenser in communication with said vessel for condensing the vapor of the excess reducing metal to a liquid and recycle equipment to recycle excess condensed reducing metal to the reactor.

62. The system of claim 61, wherein the condenser is in communication with a pump to operate at a lower pressure than the reactor, and further including heat exchange equipment in thermodynamic relationship with at least a portion of said chamber to cool the reaction products.

63. The system of claim 60, and further including a gas inlet and a gas outlet in communication with said chamber to establish a sweep gas flow path for a sweep gas to flow through the chamber to contact the reaction products to cool same.

64. The system of claim 63, wherein the sweep gas is Ar and exits the chamber with the excess reducing metal vapor, and further including a condenser for condensing the reducing metal vapor to a liquid for recycle to the reactor

thereby separating the reducing metal from the Ar and a heat exchanger for cooling the Ar and recycling the cooled Ar to the chamber.

65. The system of claim 64, wherein the sweep gas flow is countercurrent with respect to the reaction products to exit the chamber near the top thereof.

66. The system of claim 64, wherein the sweep gas flow is co-current with respect to the reaction products to exit the chamber near the bottom thereof.

67. The system of claim 66, wherein the product exits the chamber as a liquid.

68. The system of claim 64, wherein the halides are chlorides and the reducing metal is Na present in the range of from about 25% to about 85% by weight in excess of the stoichiometric amount needed to reduce the Ti chloride and/or the mixture of chloride vapor.

69. The system of claim 61, and further including a boiler for heating the Ti chloride or mixtures of Ti chloride and other chlorides before introduction to the reactor.

70. The system of claim 60, wherein the chamber is positioned generally vertically.

71. A method of producing an elemental material or an alloy thereof from a halide of the elemental material or halide mixtures comprising introducing the vapor halide of an elemental material or halide mixtures thereof into a liquid phase of a reducing metal of an alkali metal or alkaline earth metal or mixtures thereof present in excess of the amount needed to reduce the halide vapor to the elemental material or alloy resulting in an exothermic reaction producing particulate elemental material or alloy thereof and the halide salt of the alkali metal or alkaline earth metal or mixtures thereof, the temperature of the reaction products of the particulate elemental material or alloy thereof and the halide salt of the reducing metal being maintained at less than the boiling point of the halide salt of the reducing metal and greater than the boiling point of the reducing metal until substantially all excess reducing metal is vaporized, and separating the reducing metal vapor from the particulate elemental material or alloy thereof.

72. The method of claim 71, wherein the elemental material or alloy is one or more of Ti, Al, Sb, Be, B, Ga, Mo, Nb, Si, Ta, Zr, V and mixtures thereof.

73. The method of claim 72, wherein the elemental material is Ti or Zr or alloys thereof and the reducing metal is Na or Mg and the halide is a chloride.

74. The method of claim 73, wherein the reducing metal is Na present in the liquid phase in the range of from about 25% to 125% by weight in excess of the stoichiometric amount required for the reduction.

75. The method of claim 73, wherein the reducing metal is Mg present in the liquid phase in the range of from about 5% to 150% by weight in excess of the stoichiometric amount required for the reduction.

76. A method of producing an elemental material or an alloy thereof from a chloride of the elemental material or chloride mixtures comprising introducing the vapor chloride of an elemental material or chloride mixtures thereof into a flowing liquid phase of a reducing metal of sodium or magnesium, sodium if present in the liquid phase is in the range of from about 25% by weight to about 125% by weight in excess of the stoichiometric amount required for the reduction of the chloride vapor or magnesium if present in the liquid phase is in the range of from about 5% by weight to about 150% by weight in excess of the stoichiometric amount required for the reduction of the chloride vapor to the elemental material or alloy resulting in an exothermic reaction producing particulate elemental material or alloy thereof and sodium chloride or magnesium chloride and sufficient heat to vaporize substantially all the excess sodium or magnesium, and separating the sodium or magnesium vapor from the particulate elemental material or alloy thereof and sodium chloride or magnesium chloride with an inert sweep gas.

77. A method of producing an elemental material or an alloy thereof from a chloride of the elemental material or chloride mixtures comprising introducing the vapor chloride of an elemental material or chloride mixtures thereof into a flowing liquid phase of a reducing metal of sodium or magnesium, sodium if present in the liquid phase is not more than by weight in excess of the stoichiometric amount required for the reduction of the chloride vapor or magnesium if present in the liquid phase is not more than about 75% by weight in excess of the stoichiometric amount required for the reduction of the chloride vapor to the elemental material or

alloy resulting in an exothermic reaction producing particulate elemental material or alloy thereof and sodium chloride or magnesium chloride and sufficient heat to vaporize substantially all the excess sodium or magnesium, and separating the sodium or magnesium vapor from the particulate elemental material or alloy thereof and sodium chloride or magnesium chloride with an argon sweep gas.

78. A method of producing Ti or Zr or alloys thereof from a chloride of Ti or Zr or chloride mixtures comprising introducing the Ti or Zr vapor chloride or chloride mixtures thereof into a flowing liquid phase of a reducing metal of sodium or magnesium, sodium if present in the liquid phase is in the range of from about 25% by weight to about 125% by weight in excess of the stoichiometric amount required for the reduction of the chloride vapor or magnesium if present in the liquid phase is in the range of from about 5% by weight to about 150% by weight in excess of the stoichiometric amount required for the reduction of the chloride vapor to cause an exothermic reaction producing particulate Ti or Zr or alloys thereof and sodium chloride or magnesium chloride and sufficient heat to vaporize substantially all the excess sodium or magnesium while maintaining the temperature of the reaction products between the boiling point of the reducing metal and the boiling point of the salt produced, separating the sodium or magnesium vapor from the particulate Ti or Zr or alloys thereof and sodium chloride or magnesium chloride with an inert sweep gas of argon, and separating the particulate Ti or Zr or alloys thereof from the sodium chloride or magnesium chloride with water.

79. A method of producing an elemental material or an alloy thereof from a chloride of the elemental material or chloride mixtures comprising introducing the vapor chloride of an elemental material or chloride mixtures thereof into a flowing liquid phase of a reducing metal of sodium or magnesium, sodium if present in the liquid phase is in the range of from about 25% by weight to 125% by weight in excess of the stoichiometric amount required for the reduction of the chloride vapor or magnesium if present in the liquid phase is in the range of from about 5% by weight to 150% by weight in excess of the stoichiometric amount required for the reduction of the chloride vapor to the elemental material or alloy resulting in an exothermic reaction producing particulate elemental material or alloy thereof and sodium chloride or magnesium chloride and sufficient heat to vaporize substantially

all the excess sodium or magnesium, and separating the sodium or magnesium vapor from the particulate elemental material or alloy thereof and sodium chloride or magnesium chloride with an inert sweep gas.

- 80. A product made by the method of claim 1.
- 81. A product made by the method of claim 28.
- 82. A product made by the method of claim 38.
- 83. A product made by the method of claim 51.
- 84. A product made by the method of claim 79.